Beneath a deep blue sky, Peruvian small farmer Isidoro Casas Centellas lifts a wood and plastic roof panel on his low, rustic greenhouse. Although it is a modest structure made of adobe, water, and straw, something exceptional grows in the sheltered soil: onions, radishes, beets, and carrots. Agricultural economist Jorge Reinoso is astonished to see these crops. "Beets at 4,200 metres! People here have never even heard of beets," exclaims Reinoso.

Indeed, Casas is farming at the upper limits of agriculture in the Peruvian Highlands of Lake Titicaca, a region of over one million inhabitants. His community of Apopata lies in the loftiest of agroecological zones near the lake. Farming here is devoted largely to livestock production, alpacas, llamas, and a few sheep.

Below Apopata, closer to the lake and at lower altitudes (3,850 m to 3,900 m) is a second farming zone. The warmer climate permits mixed production of livestock and food and forage crops. Around the lakeshore (3,810 m) is the best farming zone -- soils are better and the warming effect of the lake is strongest.

Up in Apopata, Isidoro Casas never grew potatoes in the fields because they did not survive the frosts. But for 3 years he has been getting three harvests per year from his greenhouses. Casas is testing alternative farming technologies in an IDRC-supported project based in Puno called Sustainable Highland Agriculture or PRODASA (its Spanish acronym).

Project leader Carlos León-Velarde (please see profile in IDRC Reports, January 1995) says the technologies developed through PRODASA are intended "to meet the requirements of the present inhabitants without compromising resources for future generations. Our goal is to raise living standards, to improve well-being, access to education and communication. From the human perspective, this is a long-term goal."

Reaching these goals means adapting to highly complex farming conditions. The major constraint is extreme climatic uncertainty. Frosts or hailstorms can wipe out crops at any time of the growing season. A year of normal rainfall (around 600 mm) can be followed by a year when rain falls in flood proportions, or by drought.

**COPING WITH THE WEATHER**

Farmers have developed complex systems to cope with the variable weather conditions. Planting several crops in different plots or staggering planting times are among the techniques employed. Watching a woman sow 15 potato varieties in one tiny plot, PRODASA agronomist Roberto Valdivia observes that "this is peasant rationality, a way to protect against climatic risks."
But even these coping strategies fail to overcome low living standards -- seen in inadequate nutrition and high infant mortality. Average annual incomes range between US$800-US$1,300 per family. High population density has led to ever smaller parcels of farmland, in most cases too small to permit even subsistence agriculture. Men often must supplement family income with jobs in cities. Many inhabitants have migrated to opportunities in centres such as Puno, Arequipa, Tacna, Cuzco, and Lima.

As Valdivia points out, the productivity of the different farming zones varies greatly, determining the number of families a given area can sustain. He compares Santa Maria, a community in the middle farming zone, to Apopata, located in the highest and coldest zone. "In Santa Maria you have over 100 families living on 900 ha, whereas in Apopata there are only 67 families but they are living on 13,000 ha," says Valdivia.

The interdisciplinary PRODASA team -- including specialists in agronomy, economics, sociology, and animal sciences -- considers the whole farming system. An important aspect is to analyze the communities and households in relation to the larger region, looking for ways to exploit market opportunities and add value to raw materials through activities such as handicrafts production from alpaca and sheep fibre. The most promising candidates for market development are alpaca fibre and meat, along with quinoa and other cereals.

León-Velarde, a specialist in animal production and farming systems, works out of the International Potato Centre (CIP) in Lima, travelling frequently to the Puno Highlands. CIP and Peru's National Institute of Agricultural Research (INIA) also support PRODASA, the successor to a project funded by the Canadian International Development Agency and executed by IDRC in the mid-1980s. PRODASA is part of the Consortium for Sustainable Andean Development (CONDESAN), initiated by IDRC and CIP, presently coordinated by CIP. It links many institutions in the Andean ecoregion working toward sustainable development. The Consortium is funded by several donors, including IDRC, Swiss Development Cooperation, and the governments of Denmark, Germany and the Netherlands.

PREDICTING IMPACTS

León-Velarde tests alternative farming technologies using simulation models run on computer software. Comparing different scenarios allows PRODASA to identify the best alternatives for application in terms of benefits to families, the environment, and society at large. The models help predict the likely impact of different technologies based on variables such as available land, capital, and labour. They also move the researchers closer to answers to important questions such as whether technologies that prove sustainable at a community level are also sustainable at a regional level. The main concern for sustainability is soil erosion. Cultivation on slopes and the loss of natural vegetation and trees over many years has contributed to extensive soil erosion. Improved soil management practices are essential if the trend is to be reversed.

VALUABLE TRADITIONS

One traditional farming technique the project encourages is the aynoka, a word of the native Aymara people. The aynoka is composed of separate family plots managed by common accord. Santa Maria has nine aynokas. As Roberto Valdivia explains, a typical system would have potatoes sown in the first year, quinoa in the second, barley for human consumption in the third, and forage barley for cattle in the fourth. From years five to eight the land could lie fallow or, alternatively, be planted with alfalfa. During this period the land could also be opened for grazing. The aynoka system avoids the irrational overgrazing or overcultivation that has contributed to loss of vegetation and erosion.

Among PRODASA's technical interventions is the rustic greenhouse. "The greenhouse produces very well for our family needs. There is always something to eat and to seed," says farmer Juan Maron Acero of Santa Maria. Maron grows potatoes, lettuce and onions in his greenhouses, producing up to 30% of his family food needs. He also grows alfalfa alongside the companion grass Dactylis glomerata. This
combination produces a yield four times greater than it would in the field and feeds rabbits and guinea pigs.

**GENETIC DIVERSITY**

PRODASA, working with the Andean Roots and Tubers project within CONDESAN, is also recuperating local genetic diversity. "Genetic variety had been lost due to droughts and lack of markets," says Jorge Reinoso. Varieties stored in germplasm banks have allowed the reintroduction of abandoned crops. These include 26 potato varieties and other Andean crops such as *oca* (*Oxalis tuberosa*), *olluco* (*Ullucus tuberosum*), and *isapo* (*Tropaeolum tuberosum*). "Some varieties are low yield, but they are guaranteed to produce every year, compared to the improved varieties that may be more vulnerable to frosts and drought," says Reinoso. The genetic quality of alpaca and sheep is also being improved through the exchange of animals among local communities to bring new blood into the herds.

Other alternatives include raising trout to produce valuable protein for family consumption and for sale. In Apopata, Isidoro Casas raises trout in small ponds fed by mountain streams. The same streams supply water to wet areas -- called *bofedales* -- where the best pasture grows, and which in the dry season are essential to raising alpaca and other livestock. Encouraged by the PRODASA team, Casas is using rock barriers to divert some of the streamwater to enlarge his *bofedales*.

The project employs agricultural technicians living in the communities who work with farmers to test the best interventions. Enthusiastic farmers such as Casas are invaluable allies for technology transfer between the researchers and the farming community. PRODASA is also disseminating knowledge of viable alternatives through courses at the National University of the Altiplano in Puno. In addition, CONDESAN facilitates the exchange of experiences between PRODASA and projects in Bolivia, Colombia, Ecuador, and Peru.

Despite knowledge of farming alternatives, some are not taken up for a variety of reasons, the principal one being insufficient cash flow to cover start-up costs. "If the farmer sees that the alternative will not have a short-term return, then he won't invest in it," says León-Velarde. "They recognize utility and they invest in it. But the return has to come within one year." A community revolving fund to provide credit has succeeded in some instances -- such as providing money to buy seed potatoes. But other funds have not run smoothly when farmers have been unable to repay loans within the year owing to a bad farming season.

The lessons learned from PRODASA and other CONDESAN projects show it is unrealistic to expect poor farmers to make all the investments in better soil management and reforestation that are vital to putting highland farming on a sustainable footing. León-Velarde believes that long-term prospects for Andean mountain ecology and its inhabitants will depend to some extent on the willingness of government, private institutions, education programs, and aid programs to help farmers by investing in natural resource management and conservation projects that follow holistic and participatory approaches.

**Neale MacMillan, reporting from the Puno Highlands, Peru.**

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